IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

N07/4/CHEMI/HP3/ENG/TZ0/XX

88076103

CHEMISTRY
HIGHER LEVEL
PAPER 3

Thursday 15 November 2007 (morning)

1 hour 15 minutes

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

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Option B – Medicines and drugs

B1. Antacids can be taken for indigestion caused by excess acidity.

(a) Identify the substance responsible for the low pH value of the liquid in the human stomach. *[1]*

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(b) Two active ingredients in antacids are $Mg(OH)_2$ and $NaHCO_3$. Write an equation to show how each ingredient can relieve indigestion. *[2]*

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(c) Three antacid preparations contain 0.01 mol of one of the following – $Mg(OH)_2$, $Al(OH)_3$ and $NaHCO_3$. Identify the most effective antacid. Give a reason for your choice, with reference to the formula of the antacid. *[2]*

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B2. Refer to Table 21 in the Data Booklet when answering this question about analgesics.

(a) Describe the different ways in which mild and strong analgesics prevent pain. *[4]*

mild analgesics:. . . . . .

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strong analgesics: . . . . . .

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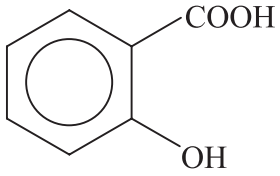
(b) Some mild analgesics are derivatives of salicylic acid. The structure of salicylic acid is



(i) Salicylic acid can be converted to aspirin. Give the formula of the group that replaces one hydrogen atom in a molecule of salicylic acid in this conversion. *[1]*

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(ii) State the names of **two** functional groups present in acetaminophen (paracetamol) and **one** functional group present in ibuprofen. *[3]*

acetaminophen (paracetamol). . . . . .

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ibuprofen . . . . . .

(iii) Identify, giving a reason for your choice, which of the analgesics in (b) (ii) exists as optical isomers. *[2]*

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B3. (a) Complete the following table, which shows the components of a mixture of three gases used in anesthetics.

Name	Formula	Partial pressure / kPa
nitrogen(I) oxide		36
	C_3H_6	12
	$CF_3CH(Br)Cl$	24

[3]

(b) (i) Determine the mole ratio of the three gases. *[1]*

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(ii) The mixture of three gases was added to oxygen at a partial pressure of 36 kPa, to form an anesthetic mixture. Determine the total pressure of the anesthetic mixture and the percentage by volume of oxygen in it. *[2]*

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B4. Discuss the arguments for and against the legalization of cannabis. *[4]*

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Option C – Human biochemistry

C1. (a) An experiment to determine the calorific value of a food product was carried out using a calorimeter. The following results were obtained:

mass of food sample burned = 5.00 g
mass of water heated = 400 g
initial temperature of water = 18.3 °C
final temperature of water = 65.1 °C

Determine the calorific value of the food product in kJ per 100 g. *[4]*

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(b) One of the ingredients in the food product is an unsaturated organic compound. A 0.01 mol sample of this compound reacts with 5 g of iodine.

Determine the number of C=C double bonds in one molecule of this compound. *[2]*

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C2. The structure of sucrose is shown in Table 22 of the Data Booklet.

(a) State the name of the oxygen-containing link between the two rings in the structure. *[1]*

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(b) Deduce the ring structures of the two monosaccharides that condense to form a molecule of sucrose. *[2]*

(c) State the empirical formula of a monosaccharide. *[1]*

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C3. The structures of three vitamins are shown in Table 22 of the Data Booklet.

(a) Predict which of the three vitamins is most soluble in water, giving a reason for your choice. *[2]*

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(b) State which **two** vitamins can be classified as primary alcohols. *[1]*

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(c) State the function of vitamin D in the human body and describe **one** effect of vitamin D deficiency. *[2]*

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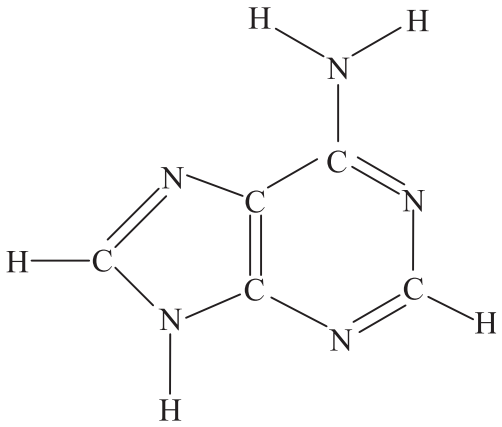
C4. A single strand of DNA consists of these components:

pentose sugar	S
organic base	B
phosphate group	P

(a) Using the letters S, B and P to represent the components, draw the structure of part of a nucleic acid containing **three** each of S, B and P. *[2]*

(b) The double helix structure of DNA is maintained by hydrogen bonding between organic bases. The structure of adenine is shown below. Draw the structure of the organic base that bonds to adenine, and circle the atoms in both bases that are involved in the bonding. The structures of other organic bases are shown in Table 22 of the Data Booklet. *[3]*



C5. Describe how the sodium-potassium pump maintains a balance between the concentrations of Na^+ and K^+ ions inside and outside body cells. *[5]*

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Option D – Environmental chemistry

D1. The combustion of fuel in cars produces several primary pollutants. Modern cars contain ways of reducing their emission of pollutants into the atmosphere.

(a) Discuss how this is done. Include in your answer *[3]*

- **two** pollutants whose amounts are reduced by recirculation of exhaust gases.
- an equation for the reaction that takes place in the catalytic converter.

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(b) The theoretical air to fuel ratio needed for the complete combustion of a typical fuel is about 15:1. A lean-burn engine uses a higher ratio than 15:1.
Write an equation to show how the amount of carbon monoxide is reduced in a lean-burn engine. *[1]*

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D2. The presence of ozone in the upper atmosphere is important for life on earth.

(a) Identify the radiation absorbed by ozone in the upper atmosphere, and describe **two** effects on life on earth that would result from a decrease in ozone concentration. *[3]*

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(b) The mechanism of the formation of ozone by natural processes can be represented by the following equations:

$$O_2 \rightarrow 2O\bullet$$
$$O_2 + O\bullet \rightarrow O_3$$

Write **two** equations to represent the depletion of ozone by natural processes. *[2]*

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D3. The treatment of waste water (sewage) is often divided into three stages. The methods used, some of the materials removed, and the substances used to remove them, can be summarized in a table. Complete the table. *[6]*

Stage	Primary	Secondary	Tertiary
Method			
Material removed	large objects		heavy metal ions
			phosphates
Substances used		oxygen bacteria	

D4. (a) Draw a Lewis structure for oxygen and for ozone. Using information from Table 10 of the Data Booklet, suggest a value for the average bond enthalpy for the oxygen-oxygen bond in ozone, giving a reason for your answer. *[4]*

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(b) Vitamin A acts as a sunscreen. The structure of vitamin A is shown in Table 22 of the Data Booklet. Explain what a sunscreen does, and identify the structural feature in vitamin A that is responsible for its action as a sunscreen. *[2]*

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D5. Discuss the contamination of drinking water supplies by mercury compounds by describing **two** different sources and **two** different effects on human health. *[4]*

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Option E – Chemical industries

E1. The extraction of lead from its ore involves several processes.

(a) Flotation (also known as froth flotation) is a physical process used to separate metal ores from the surrounding rock. Outline how this process can be used to extract galena (mostly lead sulfide, PbS) from a lump of rock. *[3]*

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(b) The lead sulfide is then heated in air (roasted) to form lead oxide, PbO, and sulfur dioxide.

(i) Write an equation for the reaction that occurs during roasting. *[1]*

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(ii) Identify a substance that can be manufactured from the sulfur dioxide formed. *[1]*

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(This question continues on the following page)

(Question E1 continued)

(c) The lead oxide is heated with coke and air in a blast furnace. Some of the coke forms carbon monoxide.

(i) Identify the type of reaction that occurs to lead oxide in the blast furnace. *[1]*

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(ii) Deduce **two** equations for reactions in which lead is formed in the blast furnace. *[2]*

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E2. Electrolysis is used to extract aluminium from alumina.

(a) The electrolytic cell is lined with graphite and filled with molten alumina and one other substance.

(i) Identify the other substance and explain its purpose. *[3]*

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(ii) The equation for the reaction occurring at the negative electrode (cathode) is

$$Al^{3+} + 3e^- \rightarrow Al$$

Write an equation for the reaction occurring at the positive electrodes (anodes), and explain why these electrodes must be replaced at regular intervals. *[2]*

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(b) Many uses of metals depend on their ability to conduct heat and electricity. Suggest **one** other property, different in each case, that makes aluminium

(i) preferable to copper in overhead electricity cables, *[1]*

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(ii) preferable to iron in saucepans. *[1]*

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E3. Describe how silicon is extracted from its oxide and how the element is purified for use in semiconductors. Give one equation for a reaction occurring in the extraction stage and one equation for a reaction occurring in the purification stage. *[6]*

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E4. The manufacture of low-density polyethene involves a free-radical mechanism in which the species RO• takes part.

(a) List the names of the three stages common to free-radical mechanisms. *[2]*

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(b) Identify a source of the species RO•. *[1]*

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(c) Write an equation to show how RO• reacts with a molecule of ethene. *[1]*

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Option F – Fuels and energy

F1. (a) One way to compare fuels is to calculate their calorific values in kJ g^{-1}. Information about three substances derived from fossil fuels is shown in the following table. *[4]*

Fuel	$\Delta H_c^{\ominus}$ / kJ mol^{-1}	M_r	Calorific value / kJ g^{-1}
C(s)			
$CH_4(g)$			
$C_8H_{18}(l)$	–5512	114.26	48.2

Complete the table using information from Tables 5 and 13 of the Data Booklet.

(b) (i) Write an equation to represent the complete combustion of methane. *[1]*

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(ii) Explain why the combustion of methane is an exothermic reaction. *[1]*

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F2. Low-grade coal can be heated with steam to produce a gaseous fuel called synthesis gas.

(a) Deduce an equation for the main reaction that occurs in the formation of synthesis gas. *[1]*

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(b) (i) Explain why the burning of synthesis gas is less polluting than burning coal. *[2]*

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(ii) State the main disadvantage of converting coal to synthesis gas as compared to burning coal directly. *[1]*

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F3. Fission and fusion are two types of nuclear reaction.

(a) Explain the relevance of the equation $E = mc^2$ to fission and fusion reactions. *[2]*

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(b) One example of a nuclear reaction is the emission of a $^{0}_{-1}e$ particle from Bi-213.

(i) Deduce the atomic number, mass number and symbol of the element formed. *[2]*

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(ii) Bi-213 has a half-life of 20 minutes. Calculate the mass of Bi-213 remaining after a 0.12 g sample of it was left for 1 hour. *[2]*

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(c) When an atom of Li-7 is bombarded with a proton, alpha particles are formed.

Deduce the nuclear equation for this reaction, showing the atomic number and mass number of each species. *[1]*

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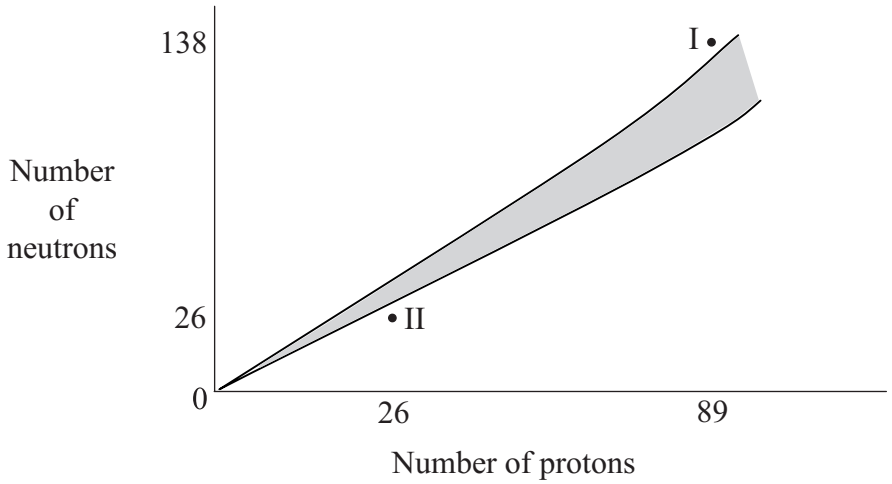
F4. The graph shows the variation of the number of neutrons with the number of protons for nuclei. Stable nuclei appear in the shaded area. The positions of two unstable nuclei are shown on the graph.



(a) Deduce the identity of each unstable nucleus using the ${}^{A}_{Z}X$ notation. *[2]*

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II . . . . . .

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(b) Predict one way in which each unstable nucleus can become more stable and write a nuclear equation for the change. *[4]*

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(This question continues on the following page)

(Question F4 continued)

(c) One process that occurs in nuclear reactions is the conversion: *[2]*

$$^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e}$$

Using information from Tables 1, 2 and 3 of the Data Booklet, calculate the energy change for this process.

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Option G – Modern analytical chemistry

G1. Identify **two** effects of the absorption of infrared radiation on the bonds in a molecule of carbon dioxide.
Explain why an oxygen molecule does not absorb infrared radiation. *[3]*

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G2. Nuclear magnetic resonance spectroscopy (^{1}H NMR) can be used to identify organic compounds.

(a) Several features of ^{1}H NMR spectra are helpful in obtaining information about the structure of a molecule. Outline what can be learned from each of the following:

- the number of peaks in the spectrum
- the ratio of areas under each peak
- chemical shift values (δ) of 1.3 and 9.7 ppm *[4]*

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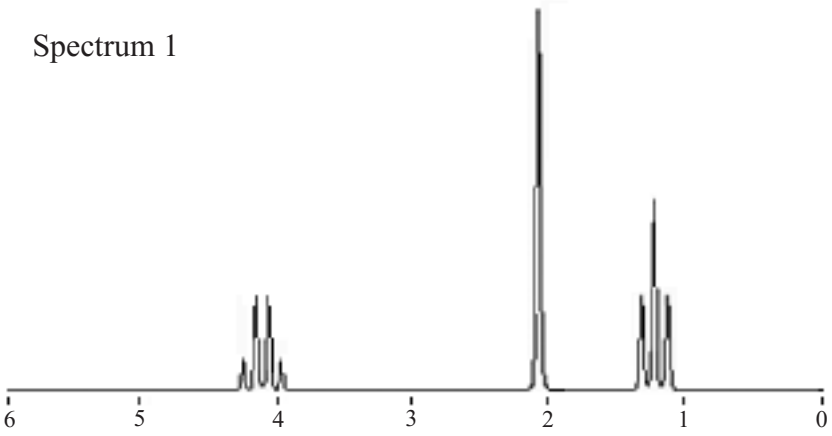
(Question G2 continued)

(b) There are four esters with the molecular formula $C_4H_8O_2$. Two of them are shown below.

ethyl ethanoate	$CH_3–COO–CH_2–CH_3$
methyl propanoate	$CH_3–CH_2–COO–CH_3$

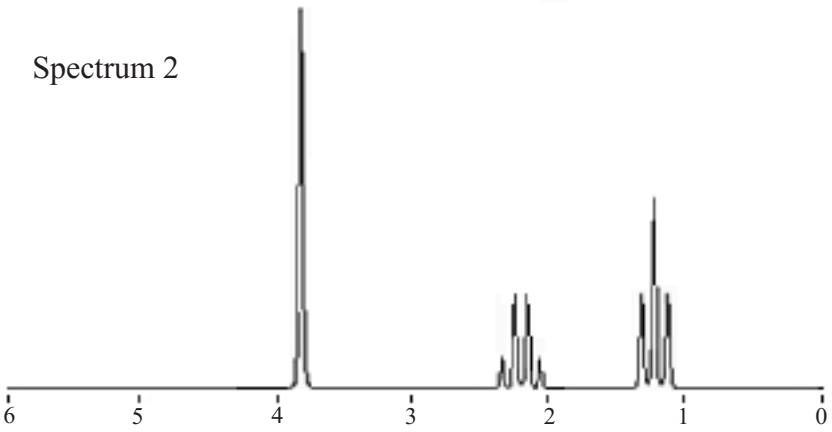
The ^1H NMR spectra of these two esters, not necessarily in the correct order, are given below.

Spectrum 1



Chemical shift / ppm

Spectrum 2



Chemical shift / ppm

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(Question G2 continued)

(i) State and explain, in terms of the structures of both esters, the origin of the triplet and the quartet. *[3]*

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(ii) Identify the origin of the singlet peak for either ester, and explain why this peak is not split. *[2]*

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(iii) By referring to the singlet peak, and using information from Table 19 of the Data Booklet, deduce which spectrum corresponds to which ester, giving a reason for your choice in each case. *[3]*

ethyl ethanoate. . . . . .

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methyl propanoate . . . . . .

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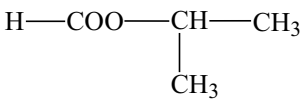
(c) Another ester with the formula $C_4H_8O_2$ has the structure



Predict the number of peaks, and the ratio of the areas under the peaks, in its ^1H NMR spectrum. *[2]*

number of peaks . . . . . .

ratio of areas . . . . . .

G3. (a) (i) Explain why the mass spectrum of 2-chloro-2-methylpropane shows molecular ion peaks at *m*/*z* values of 92 and 94 in the ratio 3:1. *[2]*

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(ii) Suggest the formulas of the species with the following *m/z* values in this spectrum:

m/*z* = 77

m/*z* = 57 *[2]*

(b) Predict the *m*/*z* values of the three main molecular ion peaks in dichloromethane. *[2]*

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(c) Mass spectra of organic compounds contain a small peak at an *m*/*z* value of one unit greater than that of the molecular ion. State what is responsible for this peak. State the information that can be obtained from the ratio of the height of this peak to the height of the molecular ion peak. *[2]*

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Option H – Further organic chemistry

H1. This question is about structural isomers and stereoisomers with the molecular formula $C_4H_6Cl_2$.

(a) The compound 1,3-dichlorobut-1-ene can be used to illustrate two types of stereoisomerism. For each type of stereoisomerism, draw two structures to show the relationship between the two. *[4]*

two geometrical isomers

two optical isomers

(b) Explain the term *racemic mixture.* *[1]*

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(c) Outline how the two optical isomers of 1,3-dichlorobut-1-ene can be distinguished from each other and from a racemic mixture. *[3]*

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(Question H1 continued)

(d) 1,3-dichlorocyclobutane exists as geometrical isomers. Draw the 3-dimensional structures of these isomers. *[2]*

H2. But-1-ene undergoes an electrophilic addition reaction with iodine chloride, ICl. The major product of this reaction is 2-chloro-1-iodobutane.

(a) Show the mechanism of this reaction, using curly arrows to represent the movement of electron pairs. *[4]*

(b) Deduce the name of the minor product of this reaction and explain why only a small amount of it is formed. *[4]*

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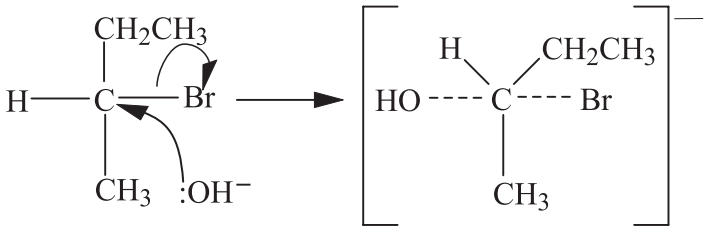
H3. Secondary halogenoalkanes can undergo nucleophilic substitution reactions by both S_N1 and S_N2 mechanisms. The mechanism showing the formation of the transition state in the reaction between 2-bromobutane and potassium hydroxide can be represented as follows.



(a) Identify the type of mechanism shown. *[1]*

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(b) State and explain how the following changes would alter the rate of the reaction by this mechanism.

(i) using water instead of potassium hydroxide. *[2]*

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(ii) using bromoethane instead of 2-bromobutane. *[2]*

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(c) Explain why chlorobenzene does not readily undergo nucleophilic substitution. *[2]*

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